Probabilistic teleportation of unknown two-particle state via POVM

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We propose a scheme for probabilistic teleportation of unknown two-particle state with partly entangled four-particle state via POVM. In this scheme the teleportation of unknown two-particle state can be realized with certain probability by performing two Bell state measurements, a proper POVM and a unitary transformation.

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Quantum teleportation is a process of transmission of an unknown quantum state via a previously shared EPR pair with the help of only two classical bits transmitted through a classical channel [1]. It was regarded as one of the most striking progress of quantum information theory [2]. It may have a number of useful applications in quantum computer [3, 4], quantum dense coding [5], quantum cryptography [6, 7, 8] and quantum secure direct communication [9, 10, 11, 12, 13].

Since Bennett et al. showed that an unknown quantum state of two-state particle (or qubit) can be teleported from a sender Alice to a spatially distant receiver Bob in 1993 [1], people have paid much attention to quantum teleportation. Research work on quantum teleportation was soon widely started up, and has got great development, theoretical and experimental as well. On the one hand, the teleportation of a photon polarization state has been demonstrated experimentally with the use of polarization-entangled photons [14] and path-entangled photons [15], respectively. The teleportation of a coherent state corresponding to continuous variable system was also realized in the laboratory [16]. On the other hand, the idea of quantum teleportation has been generalized to many cases [17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33].

Mor and Horodecki discussed the problems of teleportation via positive operator valued measure (POVM) [34], which was also called generalized measurement, and conclusive teleportation [23]. It was showed that a perfect conclusive teleportation can be obtained with any pure entangled state. Bandyopadhyay presented two optimal methods of teleporting an unknown qubit using any pure entangled state [19]. About three years ago we designed a scheme for probabilistic teleporting an unknown two-particle state with partly pure entangled four-particle state via a projective measurement on an auxiliary particle [26]. Is it possible to use POVM in the probabilistic teleportation of an unknown two-particle state with partly pure entangled four-particle state? In this Letter, we will try to answer this question, i.e., to propose a scheme for probabilistic teleportation of unknown two-particle state with partly entangled four-particle state via POVM. It will be shown that by performing two Bell state measurements, a proper POVM and a unitary transformation, the unknown two-particle state can be teleported from the sender Alice to the receiver Bob with certain probability. We state our scheme in details as follows.

Suppose that the sender Alice has two particles 1,2 in an unknown state

$$|\Phi\rangle_{12} = (a|00\rangle + b|01\rangle + c|10\rangle + d|11\rangle)_{12}, \tag{1}$$

where a, b, c, d are arbitrary complex numbers, and satisfy $|a|^2 + |b|^2 + |c|^2 + |d|^2 = 1$. We also suppose that Alice and Bob share quantum entanglement in the form of following partly pure entangled four-particle state, which will be used as the quantum channel,

$$|\Phi\rangle_{3456} = (\alpha|0000\rangle + \beta|1001\rangle + \gamma|0110\rangle + \delta|1111\rangle)_{3456}, \tag{2}$$

where $\alpha, \beta, \gamma, \delta$ are nonzero real numbers, and $\alpha^2 + \beta^2 + \gamma^2 + \delta^2 = 1$. The particles 3 and 4, and particle pair (1,2) are in Alice's possession, and other two particles 5 and 6 are in Bob's possession. The overall state of six particles is

$$|\Phi\rangle_w = |\Phi\rangle_{12} \otimes |\Phi\rangle_{3456}. \tag{3}$$

In order to realize the teleportation, firstly Alice performs two Bell state measurements on particles 2,3 and 1,4, then the resulting state of Bob's particles 5,6 will be one of the following states [26]

$$|\Psi_0\rangle_{56} = \frac{{}_{14}\langle\Phi^+|_{23}\langle\Phi^+|\Phi\rangle_w}{|{}_{14}\langle\Phi^+|_{23}\langle\Phi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\alpha|^2 + |b\beta|^2 + |c\gamma|^2 + |d\delta|^2}}(a\alpha|00\rangle + b\beta|01\rangle + c\gamma|10\rangle + d\delta|11\rangle)_{56}, \tag{4}$$

$$|\Psi_1\rangle_{56} = \frac{{}_{14}\langle\Phi^-|_{23}\langle\Phi^+|\Phi\rangle_w}{|{}_{14}\langle\Phi^-|_{23}\langle\Phi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}(a\alpha|00\rangle+b\beta|01\rangle-c\gamma|10\rangle-d\delta|11\rangle)_{56}, \tag{5}$$

$$|\Psi_2\rangle_{56} = \frac{{}_{14}\langle\Psi^+|_{23}\langle\Phi^+|\Phi\rangle_w}{|{}_{14}\langle\Psi^+|_{23}\langle\Phi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\gamma|^2+|b\delta|^2+|c\alpha|^2+|d\beta|^2}}(a\gamma|10\rangle+b\delta|11\rangle+c\alpha|00\rangle+d\beta|01\rangle)_{56}, \tag{6}$$

$$|\Psi_3\rangle_{56} = \frac{{}_{14}\langle\Psi^+|_{23}\langle\Phi^-|\Phi\rangle_w}{|{}_{14}\langle\Psi^+|_{23}\langle\Phi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\gamma|^2+|b\delta|^2+|c\alpha|^2+|d\beta|^2}}(a\gamma|10\rangle+b\delta|11\rangle-c\alpha|00\rangle-d\beta|01\rangle)_{56}, \tag{7}$$

$$|\Psi_4\rangle_{56} = \frac{{}_{14}\langle\Phi^+|_{23}\langle\Phi^-|\Phi\rangle_w}{|{}_{14}\langle\Phi^+|_{23}\langle\Phi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}(a\alpha|00\rangle-b\beta|01\rangle+c\gamma|10\rangle-d\delta|11\rangle)_{56}, \tag{8}$$

$$|\Psi_5\rangle_{56} = \frac{{}_{14}\langle\Phi^-|_{23}\langle\Phi^-|\Phi\rangle_w}{|{}_{14}\langle\Phi^-|_{23}\langle\Phi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}(a\alpha|00\rangle-b\beta|01\rangle-c\gamma|10\rangle+d\delta|11\rangle)_{56}, \tag{9}$$

$$|\Psi_6\rangle_{56} = \frac{{}_{14}\langle\Psi^+|_{23}\langle\Phi^-|\Phi\rangle_w}{|{}_{14}\langle\Psi^+|_{23}\langle\Phi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\gamma|^2+|b\delta|^2+|c\alpha|^2+|d\beta|^2}}(a\gamma|10\rangle-b\delta|11\rangle+c\alpha|00\rangle-d\beta|01\rangle)_{56}, \tag{10}$$

$$|\Psi_7\rangle_{56} = \frac{{}_{14}\langle\Psi^-|_{23}\langle\Phi^-|\Phi\rangle_w}{|{}_{14}\langle\Psi^-|_{23}\langle\Phi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\gamma|^2+|b\delta|^2+|c\alpha|^2+|d\beta|^2}}(a\gamma|10\rangle-b\delta|11\rangle-c\alpha|00\rangle+d\beta|01\rangle)_{56}, \tag{11}$$

$$|\Psi_8\rangle_{56} = \frac{{}_{14}\langle\Phi^+|_{23}\langle\Psi^+|\Phi\rangle_w}{|{}_{14}\langle\Phi^+|_{23}\langle\Psi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\beta|^2+|b\alpha|^2+|c\delta|^2+|d\gamma|^2}}(a\beta|01\rangle+b\alpha|00\rangle+c\delta|11\rangle+d\gamma|10\rangle)_{56}, \tag{12}$$

$$|\Psi_9\rangle_{56} = \frac{{}_{14}\langle\Phi^-|_{23}\langle\Psi^+|\Phi\rangle_w}{|{}_{14}\langle\Phi^-|_{23}\langle\Psi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\beta|^2+|b\alpha|^2+|c\delta|^2+|d\gamma|^2}}(a\beta|01\rangle+b\alpha|00\rangle-c\delta|11\rangle-d\gamma|10\rangle)_{56}, \tag{13}$$

$$|\Psi_{10}\rangle_{56} = \frac{{}_{14}\langle\Psi^+|_{23}\langle\Psi^+|\Phi\rangle_w}{|{}_{14}\langle\Psi^+|_{23}\langle\Psi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\delta|^2+|b\gamma|^2+|c\beta|^2+|d\alpha|^2}}(a\delta|11\rangle+b\gamma|10\rangle+c\beta|01\rangle+d\alpha|00\rangle)_{56}, \tag{14}$$

$$|\Psi_{11}\rangle_{56} = \frac{{}_{14}\langle\Psi^-|_{23}\langle\Psi^+|\Phi\rangle_w}{|{}_{14}\langle\Psi^-|_{23}\langle\Psi^+|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\delta|^2+|b\gamma|^2+|c\beta|^2+|d\alpha|^2}}(a\delta|11\rangle+b\gamma|10\rangle-c\beta|01\rangle-d\alpha|00\rangle)_{56}, \tag{15}$$

$$|\Psi_{12}\rangle_{56} = \frac{{}_{14}\langle\Phi^+|_{23}\langle\Psi^-|\Phi\rangle_w}{|{}_{14}\langle\Phi^+|_{23}\langle\Psi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\beta|^2+|b\alpha|^2+|c\delta|^2+|d\gamma|^2}}(a\beta|01\rangle-b\alpha|00\rangle+c\delta|11\rangle-d\gamma|10\rangle)_{56}, \tag{16}$$

$$|\Psi_{13}\rangle_{56} = \frac{{}_{14}\langle\Phi^-|_{23}\langle\Psi^-|\Phi\rangle_w}{|{}_{14}\langle\Phi^-|_{23}\langle\Psi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\beta|^2+|b\alpha|^2+|c\delta|^2+|d\gamma|^2}}(a\beta|01\rangle-b\alpha|00\rangle-c\delta|11\rangle+d\gamma|10\rangle)_{56}, \tag{17}$$

$$|\Psi_{14}\rangle_{56} = \frac{{}_{14}\langle\Psi^+|_{23}\langle\Psi^-|\Phi\rangle_w}{|{}_{14}\langle\Psi^+|_{23}\langle\Psi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\delta|^2+|b\gamma|^2+|c\beta|^2+|d\alpha|^2}}(a\delta|11\rangle-b\gamma|10\rangle+c\beta|01\rangle-d\alpha|00\rangle)_{56}, \tag{18}$$

$$|\Psi_{15}\rangle_{56} = \frac{{}_{14}\langle\Psi^-|_{23}\langle\Psi^-|\Phi\rangle_w}{|{}_{14}\langle\Psi^-|_{23}\langle\Psi^-|\Phi\rangle_w|} = \frac{1}{\sqrt{|a\delta|^2+|b\gamma|^2+|c\beta|^2+|d\alpha|^2}}(a\delta|11\rangle-b\gamma|10\rangle-c\beta|01\rangle+d\alpha|00\rangle)_{56}. \tag{19}$$

Here

$$|\Phi^{\pm}\rangle = \frac{1}{\sqrt{2}}(|00\rangle \pm |11\rangle), \qquad |\Psi^{\pm}\rangle = \frac{1}{\sqrt{2}}(|01\rangle \pm |10\rangle) \tag{20}$$

are the Bell states. Then Alice informs Bob her two Bell state measurement outcomes via a classical channel. By outcomes received, Bob can determine the state of particles 5,6 exactly. Without loss of generality, next we will give the case for $|\Psi_0\rangle_{56}$, the other cases can be deduced similarly. In order to realize the teleportation, Bob introduces two auxiliary qubits a, b in the state $|00\rangle_{ab}$. So the state of particles $5, 6, a, b$ becomes

$$|\Psi_0\rangle_{56}|00\rangle_{ab} = \frac{1}{\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}(a\alpha|00\rangle + b\beta|01\rangle + c\gamma|10\rangle + d\delta|11\rangle)_{56}|00\rangle_{ab}. \tag{21}$$

Then Bob performs two controlled-not operations with particles 5,6 as the controlled qubits and the auxiliary particles a, b as the target qubits respectively. After completing this operation the particles $5, 6, a, b$ are in state

$$|\Psi_0'\rangle_{56ab} = \frac{1}{\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}(a\alpha|0000\rangle + b\beta|0101\rangle + c\gamma|1010\rangle + d\delta|1111\rangle)_{56ab}. \tag{22}$$

A simple algebraic rearrangement of this expression yields

$$\begin{aligned} |\Psi_0'\rangle_{56ab} = \ & \tfrac{1}{4\sqrt{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}}[(a|00\rangle + b|01\rangle + c|10\rangle + d|11\rangle)_{56} \otimes (\alpha|00\rangle + \beta|01\rangle + \gamma|10\rangle + \delta|11\rangle)_{ab} \\ & +(a|00\rangle + b|01\rangle - c|10\rangle - d|11\rangle)_{56} \otimes (\alpha|00\rangle + \beta|01\rangle - \gamma|10\rangle - \delta|11\rangle)_{ab} \\ & +(a|00\rangle - b|01\rangle + c|10\rangle - d|11\rangle)_{56} \otimes (\alpha|00\rangle - \beta|01\rangle + \gamma|10\rangle - \delta|11\rangle)_{ab} \\ & +(a|00\rangle - b|01\rangle - c|10\rangle + d|11\rangle)_{56} \otimes (\alpha|00\rangle - \beta|01\rangle - \gamma|10\rangle + \delta|11\rangle)_{ab}]. \end{aligned} \tag{23}$$

At this stage, Bob makes an optimal POVM [19, 34] on the ancillary particle a, b to conclusively distinguish the above states. We choose the optimal POVM in this subspace as follows

$$P_1 = \tfrac{1}{x}|\Psi_1\rangle\langle\Psi_1|,\ P_2 = \tfrac{1}{x}|\Psi_2\rangle\langle\Psi_2|,\ P_3 = \tfrac{1}{x}|\Psi_3\rangle\langle\Psi_3|,\ P_4 = \tfrac{1}{x}|\Psi_4\rangle\langle\Psi_4|,\ P_5 = I - \tfrac{1}{x}\Sigma_{i=1}^4|\Psi_i\rangle\langle\Psi_i|, \tag{24}$$

where

$$|\Psi_1\rangle = \frac{1}{\sqrt{\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2}}}(\frac{1}{\alpha}|00\rangle + \frac{1}{\beta}|01\rangle + \frac{1}{\gamma}|10\rangle + \frac{1}{\delta}|11\rangle)_{ab}, \tag{25}$$

$$|\Psi_2\rangle = \frac{1}{\sqrt{\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2}}}(\frac{1}{\alpha}|00\rangle + \frac{1}{\beta}|01\rangle - \frac{1}{\gamma}|10\rangle - \frac{1}{\delta}|11\rangle)_{ab}, \tag{26}$$

$$|\Psi_3\rangle = \frac{1}{\sqrt{\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2}}}(\frac{1}{\alpha}|00\rangle - \frac{1}{\beta}|01\rangle + \frac{1}{\gamma}|10\rangle - \frac{1}{\delta}|11\rangle)_{ab}, \tag{27}$$

$$|\Psi_4\rangle = \frac{1}{\sqrt{\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2}}}(\frac{1}{\alpha}|00\rangle - \frac{1}{\beta}|01\rangle - \frac{1}{\gamma}|10\rangle + \frac{1}{\delta}|11\rangle)_{ab}; \tag{28}$$

I is an identity operator; x is a coefficient relating to $\alpha, \beta, \gamma, \delta$, $1 \le x \le 4$, and makes P_5 to be a positive operator. For exactly determining x, we would like to write the five operators P_1, P_2, P_3, P_4, P_5 in the matrix form

$$P_1 = \frac{1}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}\begin{pmatrix} \frac{1}{\alpha^2} & \frac{1}{\alpha\beta} & \frac{1}{\alpha\gamma} & \frac{1}{\alpha\delta} \\ \frac{1}{\alpha\beta} & \frac{1}{\beta^2} & \frac{1}{\beta\gamma} & \frac{1}{\beta\delta} \\ \frac{1}{\alpha\gamma} & \frac{1}{\beta\gamma} & \frac{1}{\gamma^2} & \frac{1}{\gamma\delta} \\ \frac{1}{\alpha\delta} & \frac{1}{\beta\delta} & \frac{1}{\gamma\delta} & \frac{1}{\delta^2} \end{pmatrix}, \tag{29}$$

$$P_2 = \frac{1}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}\begin{pmatrix} \frac{1}{\alpha^2} & \frac{1}{\alpha\beta} & -\frac{1}{\alpha\gamma} & -\frac{1}{\alpha\delta} \\ \frac{1}{\alpha\beta} & \frac{1}{\beta^2} & -\frac{1}{\beta\gamma} & -\frac{1}{\beta\delta} \\ -\frac{1}{\alpha\gamma} & -\frac{1}{\beta\gamma} & \frac{1}{\gamma^2} & \frac{1}{\gamma\delta} \\ -\frac{1}{\alpha\delta} & -\frac{1}{\beta\delta} & \frac{1}{\gamma\delta} & \frac{1}{\delta^2} \end{pmatrix}, \tag{30}$$

$$P_3=\frac{1}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}\begin{pmatrix}\frac{1}{\alpha^2} & -\frac{1}{\alpha\beta} & \frac{1}{\alpha\gamma} & -\frac{1}{\alpha\delta}\\ -\frac{1}{\alpha\beta} & \frac{1}{\beta^2} & -\frac{1}{\beta\gamma} & \frac{1}{\beta\delta}\\ \frac{1}{\alpha\gamma} & -\frac{1}{\beta\gamma} & \frac{1}{\gamma^2} & -\frac{1}{\gamma\delta}\\ -\frac{1}{\alpha\delta} & \frac{1}{\beta\delta} & -\frac{1}{\gamma\delta} & \frac{1}{\delta^2}\end{pmatrix}, \tag{31}$$

$$P_4=\frac{1}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}\begin{pmatrix}\frac{1}{\alpha^2} & -\frac{1}{\alpha\beta} & -\frac{1}{\alpha\gamma} & \frac{1}{\alpha\delta}\\ -\frac{1}{\alpha\beta} & \frac{1}{\beta^2} & \frac{1}{\beta\gamma} & -\frac{1}{\beta\delta}\\ -\frac{1}{\alpha\gamma} & \frac{1}{\beta\gamma} & \frac{1}{\gamma^2} & -\frac{1}{\gamma\delta}\\ \frac{1}{\alpha\delta} & -\frac{1}{\beta\delta} & -\frac{1}{\gamma\delta} & \frac{1}{\delta^2}\end{pmatrix}, \tag{32}$$

$$P_5=\frac{1}{\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2}}$$
$$\begin{pmatrix}(1-\frac{4}{x})\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2} & 0 & 0 & 0\\ 0 & (1-\frac{4}{x})\frac{1}{\beta^2}+\frac{1}{\alpha^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2} & 0 & 0\\ 0 & 0 & (1-\frac{4}{x})\frac{1}{\gamma^2}+\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\delta^2} & 0\\ 0 & 0 & 0 & (1-\frac{4}{x})\frac{1}{\delta^2}+\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}\end{pmatrix}. \tag{33}$$

Obviously, we should carefully choose x such that all the diagonal elements of P_5 are nonnegative. If the result of Bob's POVM is P_1, then Bob can safely conclude that the state of the particles 5,6 is

$$|\Phi\rangle_{56}=(a|00\rangle+b|01\rangle+c|10\rangle+d|11\rangle)_{56}. \tag{34}$$

If Bob's POVM outcome is P_2, Bob can obtain $|\Phi\rangle_{56}$ by applying the unitary transformation $\sigma_z\otimes I$ on the particles 5,6. If the Bob's POVM outcome P_3 occurs, Bob makes $I\otimes\sigma_z$ on the particles 5,6 to recover $|\Phi\rangle_{56}$. If Bob's POVM outcome is P_4, Bob applies $\sigma_z\otimes\sigma_z$ on the particles 5,6 to recover $|\Phi\rangle_{56}$. Therefore, in these four cases stated above, the teleportation is realized successfully. However if Bob's POVM outcome is P_5, Bob can infer nothing about the identity of the state of the particles 5,6. In this case the teleportation fails. As a matter of fact, the key point is that Bob never makes a mistake identifying the state of the particles 5,6. This infallibility comes at the price that sometime Bob obtains no information about the identity of the state of the particles 5,6.

By the similar method we can make the teleportation successful in the other outcomes of Alice's Bell state measurement. For the sake of saving the space we will not write them out.

Evidently, when the Bell states $|\Phi^+\rangle_{23}$ and $|\Phi^+\rangle_{14}$ are acquired in Alice's two Bell state measurements, the probability of successful teleportation is

$$\begin{aligned}&|_{14}\langle\Phi^+|_{23}\langle\Phi^+|\Phi\rangle_w|^2(1-_{56ab}\langle\Psi_0'|P_5\otimes I|\Psi_0'\rangle_{56ab})\\ =\ &\frac{|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2}{4}\times\frac{4}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})(|a\alpha|^2+|b\beta|^2+|c\gamma|^2+|d\delta|^2)}\\ =\ &\frac{1}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}.\end{aligned} \tag{35}$$

Synthesizing all Alice's Bell state measurement cases (sixteen kinds in all), the probability of successful teleportation in this scheme is

$$p=\frac{16}{x(\frac{1}{\alpha^2}+\frac{1}{\beta^2}+\frac{1}{\gamma^2}+\frac{1}{\delta^2})}. \tag{36}$$

Apparently, if the quantum channel is made up of the maximum entangled state $\frac{1}{2}(|0000\rangle+|1001\rangle+|0110\rangle+|1111\rangle)_{3456}$, i.e. $\alpha=\beta=\gamma=\delta=\frac{1}{2}$, we can choose $x=1$, then P_5 is zero operator. In this case the probabilistic teleportation becomes usual teleportation.

In summary, a scheme for probabilistic teleporting the unknown quantum state of two-particle is proposed. We hope that this scheme will be realized by experiment.

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